Protocol
1A3b: CH_4 and N_2O FROM ROAD TRAFFIC

IPCC Category:	1A3b
NFR Code:	1A3b
NOSE Code:	201
NACE Code	49.3, 49.4

Foreword
Under the Kyoto Protocol, the Netherlands is required to set up and maintain a national system to monitor its greenhouse gas emissions. One of the elements of this system is a transparent and verifiable description of the methods and processes used in this monitoring system. These methods must meet international guideline criteria, which have been defined by the United Nations (UN) and the European Union (EU).

The Netherlands meets the aforementioned requirement, for example, by defining a series of Monitoring Protocols, which describe the methods and work processes used to determine greenhouse gas emissions and the amounts of carbon sinks available. Protocols have been written for about 40 greenhouse gas sources or sinks. This document describes the protocol for one of these sources or sinks.

The protocols have been compiled in close collaboration with experts from various sectors of society in the Netherlands, particularly experts from the Emissions Registration (ER). The ER is a collaborative group that includes institutions such as CBS, WUR, RIVM and PBL. Until 31 December 2009 this was coordinated by PBL (Planbureau for the Leefomgeving, or the Netherlands Environmental Assessment Agency), but on 1 January 2010 this coordination task was taken over by RIVM (the Netherlands institute for public health and the environment). Other institutions that have contributed to the protocols include NL Agency; Ministry of Agriculture, Nature and Food Quality; and the Ministry of VROM (Housing, Spatial Planning and the Environment).

1 Scope and significance of emission sources/activities

1.1 Scope and definition
This protocol describes the calculation of N_2O and CH_4 emissions from road traffic due to the use of transport fuels sold in the Netherlands (IPCC-category: 1A3b and SBI code: 49.3, 49.4).

Road traffic consists of all motorised vehicles driving on public roads, including foreign vehicles. Road traffic includes, among other things, passenger cars, light-duty vehicles, trucks, tractors with semi-trailers, buses, special vehicles (such as fire engines and refuse trucks), motorcycles and mopeds. The N2O and CH4 emissions per unit of fuel depend on the vehicle category, fuel type, technical specifications of the engine,the availability and working of exhaust gas treatment, and the use of the vehicle (driving conditions, driving behaviour). An IPCC tier 3 methodology is used for CH4 and N2O emissions from road transport [IPCC, 2001].

1.2 Significance and influences

1.2.1 Contribution to total national emissions

Both N_2O and CH_4 emissions from road traffic contribute less than 0.5% to the Netherlands annual greenhouse gas emissions, and are thus relatively small emission sources. The contribution from road traffic to the total N_2O emissions is about 3%, whereas the share to total CH_4 emissions is less than 0,5%.

1.2.2 Major developments that infuence emissions

The following developments significantly affect emissions from these source category in the Netherlands:

- The percentages of the various fuel types (petrol, diesel, LPG) in the total fuel consumption have fluctuated over the years, in particular the percentage of diesel fuel has increased substantially
- The general growth in road mobility in the Netherlands
- The introduction and improvements of three-way catalytic converters in petrol driven cars
- The increasing use of air conditioners
- The introduction of new fuel types, such as hydrogen, biodiesel, and bioethanol/ bio-methanol

2 Method, emission factors and activity data

2.1 Calculation method

Figure1 gives a general impression of how N_2O and CH_4 emissions from road traffic are calculated.

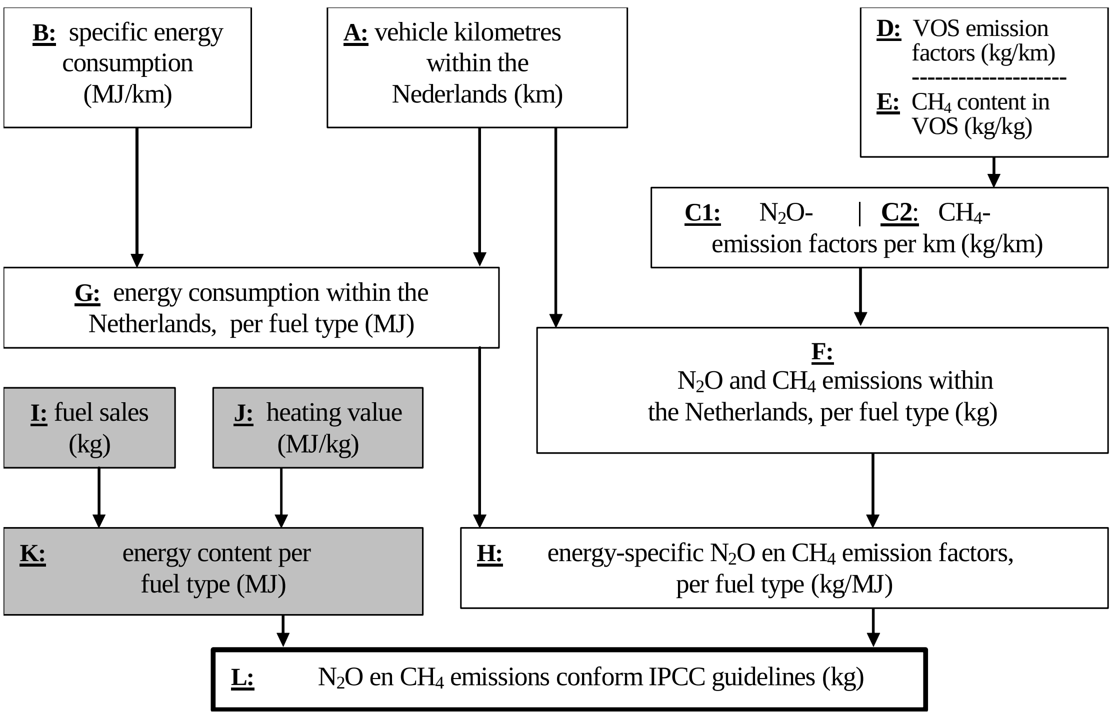

Figure 1 Calculating N2O and CH4 emissions from road traffic

The following calculations are therefore implemented:

[L] = [K] x [H], where [K] = [I] x [J]
and [H] = [F] / [G], where [G] = [A] x [B]
and [F] = [A] x [C], of which [C2] CH_4 = [D] x [E]

where:

A	= vehicles kilometres within the Netherlands (km)
B	= specific energy consumption (MJ/km)
C	= N_2O and CH_4 emission factors (g/km)
D	= VOS emission factors (kg/km)
E	= CH_4 content in VOS (kg/kg)
F	= N_2O and CH_4 emissions within the Netherlands, per fuel type (kg)
G	= energy consumption within the Netherlands, per fuel type (MJ)
H	= energy-specific N_2O and CH_4 emission factors per fuel type (kg/MJ)
I	= fuel sales (kg)
J	= heating value (MJ/kg)
K	= fuel sales, per fuel type (MJ)
L	= N_2O and CH_4 emissions conform IPCC guidelines (kg)

The N_2O and CH_4 emissions from road traffic (L) are calculated by multiplying the energy-content for all transport fuels sold in the Netherlands (K) by the energy-specific N_2O and CH_4 emission factors for the various types of fuel (petrol, diesel and LPG) (H). In order to prevent any overlap between data from the various countries, the IPCC recommends calculating greenhouse gas emissions based on fuel sales, rather than on actual fuel consumption.

The energy content for all transport fuels sold in the Netherlands (K) is calculated by multiplying the amount of fuels sold (I), taken from CBS statistics [CBSf], by the heating value of the various fuels (J) [Vreuls, 2006].

The energy-specific N_2O and CH_4 emission factors per fuel type (H) are calculated by dividing the total N_2O and CH_4 emissions per fuel type (F) by the energy consumption within the Netherlands, per fuel type (G). The emissions within the Netherlands are calculated based on the vehicle kilometres driven (A) and emission factors (C) per vehicle category, type of fuel, year the vehicle was manufactured, environmental classification, and the type of road on which the vehicle is driven. The energy consumption within the Netherlands is based on vehicle kilometres driven (A) and the specific energy consumption (B).

The underlying figures for calculating N_2O and CH_4 emissions from road traffic are published and updated annually as a set of tables that accompany the methodology report for the calculation of emissions from mobile sources in the Netherlands [Klein et al.]. Each table in the set shows the source on which the figures are based. The methodology report itself consists of a detailed description of the way in which emission factors and emissions are determined. The segments A, B, and C in Figure 1, which form the basis for F and G, are discussed further below. The relevant tables can all be found in the aforementioned set.

Vehicle kilometres for road traffic (A)

The vehicle kilometres, per year of manufacture and type of fuel, are taken from the vehicle fleet (A1) and the average number of kilometres per year driven by Dutch vehicles within the Netherlands (A3). For mopeds the only figure available is the total number of kilometres driven per year. These vehicle kilometres are then increased by the number of kilometres driven outside the Netherlands (A4). Since the N_2O and CH_4 emission factors for road vehicles also depend on the use of vehicles (driving behaviour and type of road), the calculations differentiate between driving in a built-up area, driving on motorways, and driving on other types of roads. The total kilometres per vehicle category, fuel type and year of manufacture also need to be split into these three types of roads (A5).

A1 – Road traffic vehicle fleet
The data for the number of Dutch vehicles per vehicle category, year of manufacture and fuel type are derived from the basic vehicle registration list maintained by the RDW Dienst Wegverkeer (government road transport agency). CBS-Statline database provides detailed tables per vehicle category [CBSa]. Tables 1.4 and 1.5 of the table set provide a summary thereof.

A2 – Average annual kilometres for road traffic within the Netherlands
The average number of kilometres driven per year is taken from CBS statistics for traffic performance of road traffic [CBSb, CBSc and CBSd]. Table 1.7 shows the latest figures for annual kilometres driven.

A3 - Traffic performance for mopeds
The traffic performance for mopeds is based on the Dutch mobility study (MON) [CBSe] and [RWS], as shown in Table 1.32.
A4 - Road traffic performance by foreigners
The road traffic performance by foreigners in the Netherlands (Table 1.33) is also based on CBS statistics. It is assumed that foreign cars are the same (regarding year of manufacture and environmental category) as Dutch vehicles.

A5 – Traffic performance per road category
Table 1.8 indicates the division used, per year, for traffic performance of each road type.

Specific energy consumption of road traffic (B)
Up to and including the year 1999, the specific energy consumption (Joule/km) for passenger cars was based on the Persons Auto Panel (PAP) for commercial vehicles (i.e. delivery vans, lorries and coaches) as shown on the BedrijfsVoertuigenEnquete (BVE, or commercial vehicle survey) and, for motorbikes/mopeds was based on a survey among motorbike owners. These surveys are no longer implemented. However, the resulting figures were still used, even after 2000, but over the next few years these will become increasingly out of date. Experts are therefore currently working on a new and improved set of consumption figures per year of manufacture, based on other sources. Table 1.38A provides an example of the values used for the 2005 calculations.

N2O and CH4 emission factors (C)
The N_2O and CH_4 emission factors per vehicle kilometre are also split into vehicle category, type of fuel and year of manufacture (= manufactured year emission factors).
The manufactured year emission factors for N_2O (C1) are derived from the basic factors for N_2O (Table 1.12) and the composition of the vehicle fleet per year of manufacture (Tables 1.3 and 1.3). See Section 2.2..
The manufactured year emission factors for CH_4 (C2) are derived from the manufactured year emission factors for VOS (D) and the fraction of CH_4 in the VOS emissions (E). The VOS manufactured year emission factors are shown in Tables 1.9-1.11; the CH_4 fractions are included in Table 1.31A. The manufactured year emission factors for VOS are derived from the basic factors for VOS (Table 1.35), various correction factors (Tables 1.21-1.25) and the composition of the vehicle fleet per year of manufacture (Tables 1.3 and 1.4). See Section 2.2.

Emission factors have changed over the years. For example, from 1990-1995 the N2O emission factors for petrol-based cars increased, due to the implementation of catalytic convertors from 1986 onwards. After 1995 this level reduced as a result of improvements made to these catalysers. The N_2O factors for diesel engines have also changed as a result of two developments. Firstly, the use of oxidation catalysts in cars, which have an emission factor that is twice as high as conventional diesels without oxidation catalysts. Secondly, heavy goods vehicles (that comply with EURO-3/4 emission standards) showed lower emission factors than EURO-2, EURO-1 and pre-EURO vehicles (Table 1.12).

After 1990 the CH_4 emission factors fell sharply, due to the VOS emission reductions, under the influence of European legislation concerning vehicle emissions. In particular, the implementation of catalysts (from 1986 onwards) has had a considerable positive influence.

2.2 Emission factors

Tables 9.2B and 9.2C of the table set used in the Methodiekrapport Mobiele Bronnen [Klein et al.] show the values used to calculate emissions from 1990 onwards.

The calculation begins by ascertaining the basic emission factors (grams per vehicle kilometre) per weight class, vehicle class, year of manufacture and road type. Table 1.1 shows the weight classes and vehicle classes used. Because the number of vehicle kilometres travelled is not known per vehicle class, but is known per weight class, the basic emission factors are aggregated into year-of-manufacturing factors. This takes place by first weighting the basic emission factors with the percentage of the various vehicle classes (a combination of weight and vehicle classes) into the sales of new vehicles during a specific year. The VOS (year of manufacture) figures are further corrected for the effects of cold starts, ageing, and extra emissions from the use of air conditioners, should this information be available.

The largest portion of the basic emission factors for VOS has been determined by TNO using the calculation model VERSIT+ [ref : Smit et al., 2006a; 2007]. This statistical model is based on a large amount of measurement data from all types of road vehicles used in the Netherlands. The model and the measurement data on which the model is based, are updated periodically. This means that the model results, including the basic emission factors for VOS, and the resulting emission figures, may change regularly. These changes may also effect the historic sequence. In general, only fairly new vehicles are measured, whereby new measurement results may lead to changes in recent emission years (around 3-5 years).

CH_4 emission factors are derived from the VOS emission factors, via a VOS component profile (see Table 1.31A in the table set). This VOS profile too is periodical actualized.

The basic N_2O emission factors of passenger cars for each vehicle class, fuel type and road type are based on research conducted by TNO [Feijen-Jeurissen et al., 2001]. This research indicates that the newest petrol-fuelled vehicles emit less N_2O than the first generation of such vehicles with a three-way catalyst. The extent to which this difference concerns technical advances or ageing cannot be derived from the research results. The basic factors for the other vehicle categories are based on the IPCC default values [IPCC, 1997].

2.3 Activity data

The relevant activity data for calculating N_2O and CH_4 emissions conform IPCC guidelines (L) are derived from blocks A through E as well as I and J (see Figure 1, Section 2.1). Calculations methods for N_2O and CH_4 use the total figures concerning fuel sales (I), which are published in the general Internet database known as Statline, issued by CBS [CBSf] and the heating value of the various fuels (J) [Vreuls, 2006].

The actual N_2O and CH_4 emissions within the Netherlands, calculated via blocks A through E, are also published in Statline [CBSg]. The method of calculating actual N_2O and CH_4 emissions and the energy consumption are published in the Methodiekrapport Mobiele Bronnen (methodology report for mobile sources) [Klein *et al*.].

The following table shows the most important activity data, per block, including their sources.

Activity data per calculation block, origin, source and table within the table set

	Calc. block		**Activity data derived from/based on :**	**CBS/Source**	**Table in table set**
A1	Road-traffic vehicle fleet		The number of Dutch vehicles per: - vehicle category, - year of manufacture and - type of fuel	CBSa/ RDW	 1.3 - 1.6
A2	Average nr of kms driven per year within the Netherlands		- Total km for cars OVG/MON - Nationale Auto Pas (NAP, a national car pass) for splitting the year of manufacture and fuel. - Ownership and use of commercial vehicles (road traffic statistics), source no longer available	 CBSb AVV CBSc CBSd	1.7
A3	Traffic performance for mopeds		Traffic performances for mopeds, based on the MON	CBSe RWS-MON	1.32
A4	Road traffic performance by foreigners		Traffic performance by foreigners in the Netherlands, based on CBS statistics	CBS	1.33
A5	Splitting traffic performance into road categories				1.8
B	Specific energy consumption (MJ/km)		Specific energy consumption (J/km)	TNO-VERSIT+ future	
C1	Year of manufacture emission factors N2O		- basic factors for N2O and - composition of the vehicle fleet per year of manufacture	TNO-MEP (cars) and IPCC default for others	1.12 1.3 -1.4
C2	Year of manufacture emission factors CH_4	D E	Year of manufacture emission factors for VOS (kg/km), derived from: - basic factors for VOS, - various correction factors and - composition of the vehicle feet, per year of manufacture Fraction of CH_4 in the VOS emissions (kg/kg)	 TNO- VERSIT+	1.9 -1.11 1.35 1.21-1.25 1.3-1.4 1.31A
I	Fuel sales (kg)			CBSf	
J	Specific heat per fuel (MJ/kg)			SN Vreuls	

3 Working processes

Process for estimating (t-1)
The ER produces annual preliminary emission figures for the previous year (T-1). These preliminary data are calculated by extrapolating the figures from the previous year, based on the development prognoses for the most important activity data (derived from CBS and other statistics).

Process for final determination of (t-2)
The final emission figures (as described in this protocol) are calculated using the following process.

INPUT	PROCESS	OUTPUT	BY WHOM
Fuel sales in kgs **(I)** (source: www.cbs.nl) Specific heat (MJ/kg) **(J)** (Vreuls, 2006)	**(I) x (J)**	Fuel sales in MJ per fuel type **(K)**	Statistics Netherlands
Determination of actual N_2O and CH_4 emissions **(F)** (source: www.cbs.nl) Calculation of fuel consumption **(G)**	**(F) / (G)**	N_2O and CH_4 emission factors for road traffic per fuel type in grams/MJ **(H)**	Statistics Netherlands
Fuel sales in MJ per fuel type (K) N_2O and CH_4 emissions factors road traffic per fuel type in gram/MJ (H)	**(K) x (H)**	N_2O and CH_4 emissions road traffic per fuel type in accordance with IPCC **(L)** Final data Work package leader (t-2)	Statistics Netherlands
Final data Work package leader (t-2)	Include (t-2) data in ER database	ER-db with (t-2) data	Work package leader
ER-db with (t-2) data	Check, and trend analysis of air emissions: explain deviations or modify figures	Final defined emission figures (t-2)	Task forces and PBL experts

4 Uncertainty and quality

4.1 Estimating uncertainties

A tier-1 uncertainty analysis is implemented every year before the NIR is submitted by the ER, based on the greenhouse gas inventory and in compliance with IPCC guidelines. The assumptions used (and the results thereof) are described in a background report to the NIR. In addition to this, where included in the QA/QC programme for the relevant period, extra analyses are implemented regularly in specific situations, which include any updating of the tier-2 uncertainty analyses. The annually updated QA/QC programme includes an annual revision and explanation regarding whether or not such an update is necessary for this source. The tier-2 uncertainty assessment was last updated in 2006. This assessment showed that a tier-1 uncertainty assessment is sufficiently reliable and that tier-2 uncertainty assessments need only be implemented at periodic intervals of around five years, unless a major change in an important source is sufficient to require earlier reassessment.

- Source-specific uncertainty

The uncertainty estimate-totaal concerns the root of the sum of uncertainty in the data sources used (AD_{onz}) in the square and the uncertainty of the emission factor (EF_{onz}) in the square. The extent of the total uncertainty is here primarily determined by the greatest AD or EF uncertainty.

$$\text{Uncertainty estimate}_{\text{total}} = \sqrt{EF_{onz.}{}^2 + AD_{onz.}{}^2}$$

The uncertainty estimates concerning the data sources (AD) and emission factors (EF) used, and the total uncertainty estimate, are listed in the following table.

IPCC	Category	Gas	AD $_{onz.}$	EF $_{onz.}$	Uncertainty estimates $_{tot}$
1A3	Mobile combustion: road vehicles	CH4	3,0%	60,0%	60%
1A3	Mobile combustion: road vehicles	N2O	5,0%	50,0%	50%

Activity data (AD)
The uncertainty in fuel use by road vehicles is estimated to be 2% for gasoline, 5% for diesel oil and 10% for LPG. These uncertainty estimates are based on an analysis of the annual differences per fuel type between fuel consumption according to the national approach (based on vehicle-kilometer statistics) and the IPCC approach (based on fuel deliveries to fuelling stations) [Olivier et al, 2009]. The weighted total uncertainty in activity data for CH_4 and N_2O are respectively 3% and 5%

Emission factors (EF)
For the uncertainty in emissions factors of CH_4 and N_2O from road transport, the overall emission factor uncertainty was estimated from uncertainties in the emission factors for petrol, diesel and LPG used in passenger cars with and without catalytic converter and in freight vans, and for diesel used in trucks and buses and other road transport, resulting in an uncertainty of about 60% in CH_4 and about 50% in N_2O from total road transport. In all other transport modes, the uncertainty in the CH_4 and N_2O emission factor is estimated at 100% [Olivier et al, 2009].

Annual emissions
The uncertainty in CH_4 emissions from road transport is estimated to be about 50% in annual emissions. Data on the share of CH_4 in VOC were based on information in Veldt and Van der Most (1993) and have not been validated since. Possibly, the mass fraction of CH_4 has changed, for example, because of recent changes in the aromatic content of road-transport fuels or improvements in exhaust after-treatment technology. The uncertainty in N_2O emissions from road transport was estimated to be 50% in annual emissions. Current emissions from heavy-duty diesel vehicles were probably overestimated, but, for the whole period, the overestimation affected the emission trend only slightly [Olivier et al, 2009].

4.2 Quality assurance and quality control (QA/QC)

The ER work package leaders check that:

1. the basic data are well documented and adopted (check for typing errors, use of the correct unit sizes and correct conversion);
2. the calculations have been implemented correctly;
3. assumptions are consistent, also whether specific parameters (e.g. activity data) are used consistently;
4. complete and consistent data sets have been supplied.

Any actions that result from these checks are noted on an ‘action list’. Before defining the data, supervisors check whether the relevant actions on this list, plus the QC checks, have all been completed. Defining the data is carried out by the WEM (working group on emissions monitoring), and confirmed in writing via an e-mail from the institute representatives to the ER project leader at PBL.

The work package leaders fill out a new documentation sheet when adding new data. For reasons of efficiency a minimum level has been set for obligatory documentation, i.e. 5% changes at target group level, and 0.5% at levels concerning the national total. These documentation sheets form part of the trend analysis, as well as the eventual definition of the data set.

The ER work package leaders communicate by e-mail regarding these QC checks, results and actions. They send a printed copy to the ER secretary, who keeps a logbook and compiles these e-mails into an ‘action list’. This shows explicitly that the required checks and corrections have been carried out.

4.3 Verification

In order to check the quality of the emission figures for the sources in this protocol, general QA/QC procedures have been followed that are in line with the IPCC guidelines. These are described further in the QAQC programme used by the National System, and the annual working plans published by the ER.

- Sector-specific QC
No additional specific verification procedures are implemented for the sources defined in this protocol.

4.4 Possibilities for improvement compared to the current calculation method

4.4.1 History
Not applicable

4.4.2 Future developments
Not applicable

5 Remaining aspects

5.1 Point source criteria
Traffic emissions are a diffused emissions source. This section does not apply to this source.

5.2 Component profiles
Not applicable

5.3 Regionalisation
Regionalisation is not used for the NIRs (National Inventory Reports).

5.4 Time-based variations in source strength
Not applicable

6 References and additional information

6.1 References

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6.2 Additional information

Not applicable